63-4-3

5-10-63-22

COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY, SUPPLEMENT I

SPECIAL BIBLIOGRAPHY
SB-63-49

JUNE 1963

5-10-63-22

COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY, SUPPLEMENT I

Compiled by
HELEN M. ABBOTT

SPECIAL BIBLIOGRAPHY
SB-63-49

JUNE 1963

Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

NOTICE

ABSTRACT

This annotated bibliography contains 90 selected references pertaining to composite materials.

Space flight and supersonic aircraft have made great demands for composite materials that can be used for applications that require performance characteristics not obtainable with conventional materials.

These references were selected as supplement material to a previous report; COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY – Helen M. Abbott, Lockheed Missiles & Space Company SB-62-58, February 1963.

This search covered the period from September 1962 to June 1963.

TABLE OF CONTENTS

COMPOSITE MATERIALS: AN ANNOTATED BIBLIOGRAPHY SUPPLEMENT I

by

Helen M. Abbott

1. Aclin, J. J., et al
DEVELOPMENT OF MANUFACTURING METHODS FOR GLASS FLAKE REINFORCED PLASTICS.
Olin Mathieson Chemical Corporation, New Haven, Connecticut. Interim Technical Progress Report No. 6. Mar 1962. 49p. (Contract No. AF 33(600)-41885) ASD TR 7-788 (VI).

Investigation of the suitability of glass-flake-reinforced-resin systems in commercial molding operations has been completed. Seven units which were molded are missile-stabilizer fins, practice nose cones, ablative-test nose cones, windshield inserts, rocket-exhaust cones, electronic-gate assemblies and electronic frames.

Centrifugal cast pipes have been prepared from both polyester and epoxy-resin-glass-flake systems.

The compression molding thickness study of dry blended phenolic resin, Resinox RI 4009 (Monsanto), has been completed. The physical properties of the flat sheet laminates have been determined.

2. Adler, V. E.
Nonmetallic fiber-reinforced metal composites.
ELECTRO-TECHNOLOGY. 71(1): 11–12, 1963.

Brief note on new composite materials that show potential for greater structural reliability of components and devices.

3. Armstrong, R. and R. A. Long
NARMCO ACTIVITIES IN THE FIELD OF REFRACTORY COMPOSITES. Narmco Corporation, San Diego, California. 6p. (Paper presented in NASA-ASD Sponsored Sixth Refractory Composite Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962.)

The Narmco Refractories Research Department has conducted a program on tungsten-to-graphite bonding. Certain carbide mixtures wet and adhere to ATJ graphite. This work was expanded and compatible carbide systems with both graphite and tungsten were further developed.

4. Baskey, R. H.
FIBER REINFORCEMENT OF METALLIC AND NONMETALLIC COMPOSITES. Clevite Corp., Cleveland, Ohio. Interim technical report, 17 Apr – 17 Jul 1962. 10 Aug 1962. 28p. (Contract AF 33(657)7139) ASD TR 7-924, v. 3. ASTIA AD-283 506.

Parameter studies indicated that powder metal bars of Co were reinforced by 18.6 volume % 10 mil diameter continuous W wires. The room temperature strength was increased from 48,500 psi to 85,000 psi by adding W wires. The elevated temperature (2000 F in vacuum) short time tensile strength was increased from 2,700 psi for Co to 23,600 psi by adding 18 volume % continuous 10 mil diameter W wires to a Co matrix. Parameter studies are in progress to determine the effect of wire diameter, wire length, wire spacing, wire orientation, and wire-to-matrix bond strength. Hot pressing produced composites that were 96 to 98% of theoretical density while cold pressing followed by sintering produced composites that were 80 to 90% of theoretical density depending on matrix composition.

5. Baskey, R. H.
FIBER REINFORCEMENT OF METALLIC AND MONMETALLIC COMPOSITES. Clevite Corporation, Cleveland, Ohio. Interim Technical Engineering Report, 27 Dec 1962. 28p. (Contract No. AF 33(657)-7139) ASD TR-7-924(IV).

The objective of this program is to establish parameters for the selection and application of fibers to the reinforcement of metal matrices and to demonstrate that this can be achieved through the fabrication of sheet and forged products.

The elevated-temperature (2000 F) short-time tensile strength of cobalt was increased from 2,700 psi to 23,700 psi by reinforcing the cobalt with 18 volume percent of 5 mil continuous tungsten wires. This strengthening by 5 mil wires was equivalent to 89 per cent of theoretical strengthening and was comparable to that attained by using the same quantity of 10 mil tungsten wire.

6. Bonin, J. H. and C. F. Price
THERMAL PROTECTION OF STRUCTURAL, PROPULSION, AND TEMPERATURE-SENSITIVE MATERIALS FOR HYPERSONIC AND SPACE FLIGHT. PART I: RELATIVE PERFORMANCE OF ABLATING MATERIALS EXPOSED TO LOW AND HIGH HEAT FLUX ENVIRONMENTS
Chicago Univ. Chicago Midway Laboratories, Chicago, Ill. Rept. for Aug–Oct 1958, on Materials Analysis and Evaluation Techniques. May 1960. 54p. (Contract AF 33(616)6006) WADC TR 59-366, Pt. 1. ASTIA AD-241 452.

A comparison was made of the relative performance of ablating materials with heat-sink materials on a weight-per-unit-area basis when exposed to thermal environments associated with recoverable space capsule trajectories. An air heater was designed for the low-heat phase to heat 130 to 150 cu ft/min of air from 1000° and 2000° F. This phase lasted about 500 sec. A 1.1-megawatt air arc was used in the high-heat phase to yield a heat flux rate corresponding to ICBM re-entry conditions. The high-heat phase lasted about 100 sec. The samples consisted of slabs of the following materials which were attached to aluminum backing plates with epoxy resin: (1) nylon-, cotton-, asbestos-, and glass-fabric-reinforced phenolic resins, (2) cotton-reinforced melamine resin, (3) methyl methacrylate, (4) refrasil-reinforced phenolic-type resin, (5) glass-fiber-reinforced silicone, (6) nylon-fiber-reinforced acrylic resin, and (7) Teflon. The effective heat capabilities ranged from 1590 to 4770-BTU/lb. Generally, the pure ablators were inferior at high heat fluxes although as compared to copper and beryllium, good heat-sink materials, the effective heat capabilities were from 2 to 5 times as high as beryllium.

7. Bouc, C. A.
MICROSCOPIC STUDY OF MODE OF FRACTURE IN FILAMENT WOUND GLASS-RESIN COMPOSITES. University of Illinois, Urbana, Illinois. Naval Research Laboratory. T&AM Report No. 234. Nov 1962. 31p. Tech. Memo No. 189. (Contract No. Nonr 2947(2)(x))

Filament-wound glass-resin specimens were successfully developed to approximately simulate a typical filament-wound composite such as are found in pressure vessels and fuel tanks. During tensile loading, each specimen was carefully scanned through a microscope at a magnification of x200, and a written and photographic record was made of the progress of the fracture phenomena. The information thus obtained was synthesized into identification of five different microscopic modes of fracture. The origin and nature of these different fracture modes was investigated with the aid of microphotographs, and their contribution to the progressive and ultimate fracture of the specimens determined.

8. Bourdeau, R. G. and F. E. Papalegis
RESEARCH ON NEW AND IMPROVED THERMALLY PROTECTIVE FIBER REINFORCED COMPOSITE MATERIALS. High Temperature Materials, Inc., Boston, Mass. Progress Report. Feb 1963. 26p. (Contract AF 33(657)-8651)

Pyrolytic graphite whiskers with diameters as small as 4 to 5 microns and with lengths greater than two inches have been grown. These whiskers were also obtained in high concentrations with little bridging from one to another. Whisker tensile strengths were measured and an appreciable increase in strength was observed with improved surface characteristics; strengths from approximately 60,000 psi to 340,000 psi were obtained. Commercially available graphite filaments surfaced with pyrolytic graphite were heat treated to temperatures over 3000° C, and a marked increase in filament flexibility

was obtained. These filaments can be bent repeatedly to small radii without failure. Oxidation tests of treated and untreated carbon filaments showed the greater oxidation resistance of pyrolytic graphite surfaced filaments over the base filaments. As-received graphite filaments were also improved by a pyrolytic graphite surfacing.

9. CARBON-BASE FIBER REINFORCED PLASTICS.
Aeronautical Systems Division, Dir/Materials
and Processes, Nonmetallic Materials Laboratory,
Wright-Patterson AFB, Ohio. Final report.
Rpt. Nr ASD-TDR-62-635. Aug 1962. 60p.

Current research on high-temperature materials has lead to the development of a new class of nonmelting filamentous materials. These fibers are carbonaceous in composition, and hold great promise for use as reinforcing agents in both structural and ablative plastic composites.

First generation developments in carbon-base fiber technology are reported. Techniques for synthesizing the fibered materials are discussed, together with the properties and characteristics of available materials. Unique plastic composites were prepared using carbon-base fibers and fabrics. Initial empirical results indicate that the composites are useful for both high-temperature structural and ablative purposes.

Additional improvements will be required to realize the inherent potential of carbon-base fibers. Several technical recommendations are given for eliminating current material deficiencies and improving fiber properties.

10. Carroll, M. T. and D. J. Pritchard
ENGINEERING RESEARCH – SEALING –
METAL-FIBER COMPOSITE – EVALUATION OF.
General Dynamics, Fort Worth, Tex.
Report no. ERR-FW-121. 30 Dec 1961. 16p.
(Contract AF 33(657)7248) ASTIA AD-289 074.

A silver impregnated metal-fiber composite seal was received for testing as a fuel seal in the temperature range of -100 F to +1200 F. The seal was a flat circular gasket 8 1/4 in. in diameter and .031 in. thick. Sealing properties at room temperature were determined by installing the seal between the faying surfaces of a steel test tank and applying internal pressures from 5 to 30 psi. An air tight seal at room temperature could not be obtained with this composite fiber-metal seal.

11. **Chao, P. J., et al**
RESEARCH IN PROTECTIVE COATINGS FOR REFRACTORY METALS. The Pfaudler Company, Rochester, New York. Rept. No. PF 62-7. 15p. (Paper presented at the NASA-ASD Sponsored Sixth Refractory Composite Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962.)

This report summarizes the experimental work performed at Pfaudler since the 1961 meeting of the Refractory Composites Working Group on protective coatings for molybdenum, columbium, and tantalum alloys. The research range from early laboratory evaluation of coating systems to scale-up of a proved coating, and included process development as well as coating-systems development.

12. Clausen, E. M., D. M. Krumwiede, et al
SYNTHESIS OF FIBER REINFORCED INORGANIC LAMINATES. Illinois University, Urbana. Final rept., 1 Apr 1960–15 Aug 1961 on Nonmetallic and Composite Materials. Jun 1962. 63p. (Contract AF 33(616)6283, Proj. 7340) WADD TR 60-299, pt. 2. ASTIA AD-293 930

Studies directed toward the use of inorganic materials as the matrix for reinforced composites were concerned with effects of compositional and processing variables on matrix strength, the explanation of the observed deformation of matrix bodies, and research on protective fiber coatings. Type of bonding acid used, premilling time of dry raw materials, reacting temperature, and milling time of reacted materials were considered as variables affecting matrix strength. Reactions occurring during drying and firing, and the mechanism of deformation were investigated using X-ray, light microscopy, and electron microscopy techniques. Deformed specimens were thought to contain concentrated areas of A1203 crystals and a slightly more amorphous matrix. One of these differences might be the cause of deformation. The strength and corrosive effect of matrices on A1203, Ti02, and Zr02 rods were examined. Modulus of rupture values for E38 (H3P04 content = 37.4%; H3PO3 content = 3.3%) matrix bars containing A1203 rods were the highest.

13. Davis, R. M. and C. Milewski
HIGH TEMPERATURE COMPOSITE STRUCTURE.
Martin-Marietta Corp., Baltimore, Md.
Final report, Jul 1960--Jun 1962 on Construction Techniques and Applications of New Materials.
Sep 1962. 253p. Research report no. 30. (Contract AF 33(616)7497, Proj. 1368) ASD TDR 62-418.
ASTIA AD-289 092.

Two re-entry heat shield systems intended for efficient operation with surface temperatures in the range of 3000 to 4000°F when adapted to spherical nose cap shapes were designed, developed, fabricated, tested and evaluated. The heat shields were of the radiated type, utilizing a foamed aluminum oxide material in the structural insulation design concept. Dense facings and resin impregnation were used to alter the basic foam, with the latter proving the better modification as shown by simulated re-entry tests in a large hot gas facility. Effects of various combinations of plasma jet enthalpy and heating rates on resin-impregnated ceramic foams were compared. These more closely simulated re-entry conditions for ablative (and semi-ablative) type materials.

14. Ekvall, J. C.
EVALUATION OF MONOFILAMENT COMPOSITES.
Lockheed-California-Burbank Report No.
LAC-LR-16498. 14 Dec 1962.

This report is an evaluation of monofilament composite constructed from high strength glass and epoxy resin. The filament material used in this investigation was X994 glass, a recently developed product of Owens-Corning Fiberglas.

15. Fechek, F. and R. Tomeshot
Reinforcements – Air Force approach to planned composite properties. In SOCIETY OF THE PLASTIC INDUSTRY, REINFORCED PLASTICS DIVISION, ANNUAL TECHNICAL AND MANAGEMENT CONFERENCE, 18TH PROCEEDINGS. NEW YORK, SOCIETY OF THE PLASTICS INDUSTRY, INC. USAF, Systems Command, Aeronautical Systems Division, Directorate of Materials and Processes, Wright-Patterson AFB, Ohio. 1963. 8p.

Brief discussion of Air Force research on reinforcement materials. Considered are both vitreous and nonvitreous filaments. The latter include polycrystalline filaments of zirconia, alumina, and beryllia.

16. Gibeaut, W. A. and D. J. Maykuth
SUMMARY OF THE SIXTH MEETING OF THE REFRACTORY COMPOSITES WORKING GROUP. Defense Metals Information Center, Columbus, Ohio. DMIC rept. no. 175. 24 Sep 1962. 65p. (Contract AF 33(616)7747, Proj. no. 2(8-8975) ASTIA AD-287 029.

Information on refractory composites for use above 2500° F, presented at the Sixth Refractory Composites Working Group Meeting in Dayton in June, 1962, is summarized. Protective coatings, insulating ceramics, dispersion strengthening, plasma spraying, high-temperature reactions, and testing techniques were discussed. The time-temperature capabilities of metallic and inter-metallic coatings for Va, Nb, Mo, Ta, and W are steadily being increased by improved processing techniques and chemical modification. Insulating ceramics were developed for critical nose-cap and other applications. Structural and thermal stability are reported at 3500° F for A1203-base systems and at 4200° F for ZrO2-base systems. Graphite, a refractory material which lacks oxidation resistance, was chemically modified to improve oxidation performance markedly at temperatures up to 4200° F.

17. Giemza, C. J., W. B. Hunter, et al
HIGH TEMPERATURE – COMPOSITE STRUCTURES. Aeronca Mfg. Corp., Middletown, Ohio. Interim technical documentary progress rept., 1 Oct–31 Dec 1962. 31 Dec 1962. 89p. (Contract AF 33(657)7151, Proj. 7-845) ASD TR 7-845, v. 5. ASTIA AD-294 732.

The objective of this program is to evolve new manufacturing concepts for re-entry structures in which a reinforced ceramic heat shield and load bearing honeycomb structure will be integrated. Because of the radical departure from conventional structural design, the solution has required a systematic relation among design, development of manufacturing processes, and testing. The load bearing semi-monocoque structure is designed to operate in a temperature environment within a range which is metallurgically stable for beryllium, stainless steels, and superalloys. A ninety-inch full scale section of a possible lifting body reentry structure is being fabricated for subsequent test under simulated super-orbital re-entry conditions.

18. Gorton, C. A., C. C. McMahon, and J. A. Rizzardi
ULTRA-FINE HIGH TEMPERATURE, HIGH STRENGTH METALLIC FIBERS. Hoskins Manufacturing Company, Detroit, Michigan. Final Report, Part 1. Aug 1962. 70p. (Contract No. AF 33(616)-8366) ASD TDR 62-727.

Eight superalloys of A-285, Elgiloy, Hastelloy B, M-252, René 41, Udimet 500, Udimet 700, and Waspaloy were processed to ultra-fine fibers of approximately 0.001-inch diameter or less and evaluated for drawability. The room-temperature mechanical properties of the annealed fine fibers are presented. The effect of cold reduction on the mechanical properties is also included. The Elgiloy and Hastelloy B alloys processed more readily with less die wear than the remaining alloys.

The tensile strength at room temperature of each of the alloys, except A-285 was within the range of 160,000 to 220,000 psi as solution heat treated. Alloy A-286 tensile strength was approximately 100,000 psi. The alloys in order of decreasing strengths were U-700, René 41, Hastelloy B, Wrspaloy, U-500, M-252, Elgiloy, and A-286.

Multifilament yarns composed of 7, 19, and 37 filaments of Elgiloy and Rene' 41 were successfully processed to less than 0.003-inch diameter when sheathed with alloy Chromel-C, but the sheath could not be removed without damaging the fibers. High-temperature tensile tests of the sheathed yarn at 1600° F, 1800° F, and 2000° F in air and argon atmospheres indicated increased strength in order of increased number of filaments. The Chromel-C sheath protected the core fibers from oxidation and improved the high-temperature strength of the yarn at 1800° F and 2000° F

19. Hall, W. B., J. H. Lauchner, and J. M. Fields, Jr.
HIGH TEMPERATURE INORGANIC STRUCTURAL COMPOSITE MATERIALS. Mississippi State Univ. Quarterly progress report no. 3. Jul–Sep 1961. (Contract AF 33(616)7765(3))

Physical properties of E-18 matrix were determined, dry pressing parameters studied and preliminary attempts made to form composites by other than dry pressing.

20. Hall, W. B., J. H. Lauchner, et al
HIGH TEMPERATURE INORGANIC STRUCTURAL COMPOSITE MATERIALS. Mississippi State U., State College. Quarterly progress report no. 5, 1 Apr--30 Jun 1962. Jul 1962. 15p. (Contract AF 33(616)7765, Proj. 1(8-7340)) ASTIA AD-291 863.

A new matrix material was developed which has a lower corrosion rate upon inorganic reinforcement fibers. Preliminary evaluation of this new phosphate bonded body was completed. Electron micrographs of bodies processed at different temperatures are included. An automatic stress-strain apparatus was completed and calibrated. Data and graphs are included for E-18 and amblate matrixes.

21. Harris, G. M.
DEVELOPMENT OF POROUS FUSED SILICA COMPOSITES, PROPERTIES, AND APPLICATIONS. Avco Corporation, Wilmington, Mass. 3p. (Paper presented at the NASA-ASD Sponsored Sixth Refractory Composites Working Group Meeting, Dayton, Ohio, 17--19 Jun 1962.

A family of porous fused silica insulation materials has been developed at the Avco Research and Advanced Development Division. Physical-strength property data are given.

It is assumed that a change in density will produce a change in physical, electrical, and thermal properties so that the values given may be considered at the mid-range of the present family of silica materials.

22. Headrick, R. E.
COMPOSITE SEAL MATERIALS FOR EXTREME ENVIRONMENTS. Directorate of Materials, Wright-Patterson Air Force Base, Ohio. Final Report. Mar 1962. 23p. ASD TDR 62-286. ASTIA AD-274082.

Unusual and extremely promising composite-seal materials are critically discussed. Evaluation of these materials, metal-fiber skeletons impregnated with softer organic and inorganic materials, as seals at both static and dynamic conditions from liquid-nitrogen temperatures to 1000° F and at pressures up to 5000 psi have yielded unsurpassed results. The metal fiber skeletons (stainless steel or molybdenum) provide the strength and resilience, and the impregnating materials (soft metals, soft metal alloys, or compounded polymeric materials) provide the sealing barrier. In some cases the impregnants have increased the resilience and lubricity of the composite. The limitations, potentials, and the availability of these materials are discussed.

23. Henderson, C. M.
REFRACTORY COMPOSITE MATERIALS RESEARCH AT MONSANTO RESEARCH CORPORATION. Monsanto Research Corporation, Boston Massachusetts. 13p. (Paper presented at the NASA-ASD Sponsored Sixth Refractory Composites Working Group Meeting, Dayton, Ohio, 16 Jun 1962.)

Monsanto Chemical Company has for a number of years conducted proprietary research on materials and processes oriented towards refractory composites. This research has concerned synthesis, production and testing of:

1. Fine particle powders for use in refractory coatings, ceramics, and powder metallury applications.
2. Refractory metal, cermet and ceramic materials exhibiting unusual high-temperature mechanical and physical properties.

Materials considered were: single metal oxides (such as alumina, thoria, iron oxide, silica, stannic oxide, zirconia, urania, nickel oxide, hafnia, zinc oxide, titania, ceria, chromia, cobalt oxide, and lanthanum oxide); oxide compounds; and fine particle composite powders (such as nickel-thoria, nickel-ceria, nickel-alumina, tungsten-thoria, tungsten-alumina, platinum-thoria, platinum-alumina, silver-alumina, cobalt oxide-iron oxide, alumina-tin oxide, calcium oxide-magnesia-zirconia); and fine particle metal powders (such as nickel, tungsten, cobalt, copper, silver, platinum, iridium, palladium, silver-palladium, and iron-nickel.

24. Herron, R. H.
PROGRESS REPORT ON CHROMIUM COMPOSITE MATERIALS. The Bendix Corporation, South Bend, Ind. 13p. (Report presented at the NASA-ASD Sponsored Sixth Refractory Composites Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962.

The work at Bendix since the last working group meeting has been concentrated primarily in further development and evaluation of the chromium composite materials previously reported. The basic material, a chromium-magnesium oxide composite, has been investigated to determine self-forming oxidation protection layers, ductility at room temperature as extruded and after reheating in air, and forming properties.

25. HIGH-TEMPERATURE RESISTANT BERYLLIA FIBER-REINFORCED STRUCTURAL COMPOSITES. National Beryllia Corp., Haskell, N.J. July 1962. 101p. (Contract AF 33(616)8066, Proj. 7340) ASD TDR 62-632. ASTIA AD-291 545.

Of the various types of materials suitable for advanced high-temperature reinforcements, BeO shows a strong potential because of its combination of high melting point and low density. High purity BeO fibers have been prepared by two methods with reproducible results; the first, evaporation of BeO by water vapor at high temperatures with subsequent condensation as BeO fibers; and the second, oxidation of beryllium metal in a hydrogen carrier gas with condensation of monocrystalline highly oriented BeO fibers. Best quality and mechanical properties have been found in the latter type. Such pure BeO monocrystalline fibers have been grown in lengths of 1 1/4 inches with a thickness of approximately .0005 inches. Specimens of BeO reinforced binders were prepared to demonstrate composite fabrication feasibility.

26. Hollinger, D. L. and H. T. Plant
HIGH STRENGTH GLASS FIBERS DEVELOPMENT PROGRAM. General Electric Company, Evendale, Ohio. SPN, 4th Bi-Monthly Progress Report. 20 Jan 1963. 20p. (Contract No. NOw 61-0641-c (FBM))

Work during this period has demonstrated that the tensile strength of E-glass fibers approaches 1,000,000 psi when measured at liquid-nitrogen temperature (77 K). These same fibers showed strengths averaging 500,000 psi when tested at normal room temperature and humidity. The higher measured strength of low temperature is believed to be the true instantaneous strength of the fiber when chemical reaction with its environment is suppressed.

Composite rings of E-glass monofilament and epoxy resin exhibit the same percentage increase over room-temperature strength when tested at liquid-nitrogen temperature as do the bare fibers from which they are made.

27. Iwatsuki, F., L. L. Smith, et al
COMPOSITE INORGANIC RESILIENT SEAL MATERIALS. Amour Research Foundation, Chicago, Ill. Progress report no. 7, 1 Apr–30 Jun 1962. 30 Jun 1962. 22p. (Contract AF 33(616)7310, Proj. 1 (8-7340)) ASTIA AD-291 984

Research was conducted to investigate and develop composite materials for use as static and dynamic seals at temperatures ranging from cryogenic to 2000° F, and at pressures up to 5000 psi. Emphasis is being placed on dynamic seals for rotating and reciprocating shafts covering the temperature range -320 to 1500° F and on low temperature, low clamping force static seals for sealing the cabins of space vehicles. Efforts included high temperature evaluation of large static rings, cryogenic evaluation of static seals, dynamic fixture design, and sample preparation for the determination of mechanical properties at elevated temperatures.

28. Javitz, Alex E. and H. E. Barkan
Multifunctional composite materials in environmental design problems – Part 1. ELECTROTECHNOLOGY. 70(5): 104–114, 1962.

Problem areas and materials are discussed and comprehensive data charts are provided.

29. John, R. R.
INVESTIGATION OF BEHAVIOR OF NEW PLASTIC AND COMPOSITE MATERIALS. Avco Corp., New York, N.Y. Quarterly progress report no. 2, 1 Oct–15 Jan 1963. 1 Feb 1963. 3p. (Contract AF 33(657)-8892)

Seventeen samples were obtained and tested. The samples were reinforced plastics consisting of either carbon or refrasil reinforcing agents and a series of different chemical resins as binders. The specimens were tested in a subsonic jet at a nominal pressure of 1 atmosphere, a heat flux of 1050 BTU/ft^2/sec, and an air enthalpy of 8150 BTU/lb. Measurements were made of the time-history of the sample surface recession, sample brightness surface temperature, and surface radiation.

30. Johnson, D. E., et al
METAL FILAMENTS FOR HIGH-TEMPERATURE FABRICS. Little (Arthur D.) Inc., Cambridge, Mass. Wright-Patterson AFB, Ohio, Aeronautical Systems Division. Final Report, May 1960 through Dec 1961. Feb 1962. 183p. (Contract AF 33(616)-7294) ASD-TR-62-180. (Available to U.S. Government agencies and contractors only.)

This research was primarily on the oxidation and tensile properties of 0.5- to 5.0-mil filaments of three superalloys (Elgiloy, René 41, and Inconel 702) and two refractory metals (tungsten and molybdenum) in the 1500° to 2000°F temperature range. The oxidation data for the refractory metals are for ultra-short-time durations, up to 100 milliseconds. Preliminary creep rupture data are also given for the above three superalloys, along with some data for Karma and Nichrome V. Attempts to develop very thin (0.5- to 0.1-mil oxidation-resistant coatings for molybdenum and tungsten by the use of various plating techniques are also reported. One-half-mil fibers of superalloy wire were woven into fabrics of various constructions; the influence of fabric construction on permeability and aerodynamic drag (at Mach 4.8) is discussed. The literature pertaining to heat transfer to single cylinders in hypersonic flow is reviewed, and sample calculations of equilibrium temperature are made to point up areas where the data are deficient. This report also presents the results of preliminary research on three new techniques for forming fine filaments without the use of a diamond die.

31. Kelsey, R. H.
REINFORCEMENT OF NICKEL CHROMIUM ALLOYS WITH SAPHIRE SHISKERS. Horizons Incorporated, Cleveland, Ohio. Interim report no. 1, 28 Sep–28 Dec 1962. 19 Feb 1963. 34p. (Contract NOw-63-0138-c)

Strong bonding of iron, nickel, chromium and 347 stainless steel to pure alumina disks has been accomplished. The pure metals, in the presence of their naturally occurring oxides, could be bonded without additives; alloys of the same metals required additives for the formation of a strong bond. Small amounts of aluminum metal and/or calcium ion have been found to promote the formation of a bond between 347 stainless steel and alumina, and between 80/20 nickel/chromium alloy and alumina. Study of the thermodynamics of the system iron/oxygen/alumina indicate that dissolved oxygen may play an important role in the formation of the metal-whisker bond.

32. Kliman, M. I.
IMPACT STRENGTH OF ALUMINA FIBER-CERAMIC COMPOSITES. Watertown Arsenal Laboratories, Mass. Technical report on Materials for Army Weapons and Combat Mobility. Technical report no. WAL TR 371/51. Nov 1962. 9p. (Proj. 59332007) ASTIA AD-291 826.

The use of randomly dispersed aluminum oxide fiber to impart increased impact strength to a procelain body and to a refractory aluminum phosphate-bonded alumina body is reported. The improved impact strength is either retained or increased at elevated testing temperatures. The variation of impact strength with alumina fiber content was determined for the fiber-ceramic body composites.

33. Kliman, M. I.
TRANSVERSE RUPTURE STRENGTH OF ALUMINA FIBER-CERAMIC COMPOSITES. Watertown Arsenal Laboratories, Mass. Technical report no. WAL TR 371/53. Nov 1962. 13p. (DA Proj. 59332007) ASTIA AD-291 883.

The utilization of high strength alumina fiber to reinforce a wide range of ceramic bodies is reported. The transverse rupture strength of these composite structures is markedly increased over that of the bodies without alumina fiber content. The variation of strength increase with alumina fiber content is reported for composites of alumina fiber combined with portland cement; an unfired procelain body; glass; a porcelain body; and phosphate-bonded alumina.

34. Krock, R. H., G. Levy, and L. A. Shepard
PREPARATION OF IDEALIZED TWO PHASE COMPOSITES BY ELECTROPLATING. Aeroelastic and Structures Research Laboratory, Mass. Institute of Technology, Cambridge. Report no. ASRL TR 94-2. Aug 1962. 15p. (Contract AF 49(638)775, Proj. 9782) ASTIA AD-287 948.

Two phase composites, whose microstructure consists of steel ball bearings uniformly dispersed in Ag matrix, were prepared by electroplating. Sintering of the composite raft after electro-plating removed remaining voids and removed boundaries between particles by grain growth and diffusion. This method is capable of producing a two phase composite with careful control of particle size and interparticle spacing, unobtainable by previous methods.

35. Krock, R. H. and L. A. Shepard
MECHANICAL BEHAVIOR OF THE TWO-PHASE COMPOSITE, TUNGSTEN-NICKEL-IRON. Aeroelastic and Structures Research Laboratory, Mass. Institute of Technology, Cambridge. Report no. ASRL TR 94-4. Aug 1962. 33p. (Contract AF 49(638) 775, Proj. 9782) ASTIA AD-288 915.

A series of ductile, two phase W-Ni-Fe composites, sintered in the presence of a liquid phase, were tested in tension. Identical room temperature stress-strain curves were obtained for specimens containing from 80 to 92 wt-% W (58 to 75 vol-% W particles). The composites exhibited a maximum elongation of 29% at room temperature, and 10.7% at 77 K. The W particles in the composite elongated by the same amount at these temperatures. Single phase hmmoy specimens matching the composition of the composite matrix showed about one-half the flow stress of the composites. The test results demonstrated that the mechanical properties of W-Ni-Fe composites are determined by the W particles alone and are independent of matrix volume fraction or mean free path over the composition range studied.

36. Krusos, J. N., A S. Kjelby, et al
BERYLLIUM COMPOSITE STRUCTURES. VOLUME I. DESIGN AND APPLICATION. Aeronca Mfg. Corp., Middletown, Ohio. Final technical engineering report, 4 Feb 1960–31 Aug 1961 on Design Technologies and Structural Configuration Concepts for Aerospace Vehicles. May 1962. 169p. (Contract AF 33(616)7050, Proj. 1368) ASD TR 61-706, v.1. ASTIA AD-282 003.

Design information is presented for Be and ceramic composite structures for re-entry vehicle applications. A summary of materials and process developments for Be panels and heat shield ceramics, analytical evaluations, and discussion of application of insulated structural concepts to re-entry vehicle systems are included. Also included are the results of panel tests in the severe environments of turbojet and ramjet exhausts. Data suitable for preliminary design considerations are presented for three reinforced heat shield ceramic foams: Al203, Si02, and ZrO2. Be sandwich panels constructed in the course of the program are described with regard to fabrication potential and performance in aerospace structures.

37. Krusos, J N., A S. Kjelby, et al
BERYLLIUM COMPOSITE STRUCTURES. VOLUME II. MATERIALS AND PROCESSES. Aeronca Mfg. Corp., Middletown, Ohio. Final technical engineering report, 4 Feb 1960–31 Aug 1961 on Design Technologies and Structural Configuration Concepts for Aerospace Vehicles. May 1962. 313p. (Contract AF 33(616)7050, Proj. 1368) ASD TR 61-706, v.2. ASTIA AD-278 526.

The methods developed for fabrication of Be sheet composite structures are described. Descriptions and performance evaluation are included for a variety of panels fabricated under the contract consisting of Be load bearing panels and porous ceramic heat shields developed to withstand temperatures in excess of 3000° F. Concepts are outlined defining application of Be-ceramic composites to aerospace vehicle structures. Be sheet fabrication methods and tooling are described and include such processes as cutting, forming, chem-milling, and brazing. Be sheet faces were brazed to a variety of superalloy and stainless steel honeycomb cores. Three basic porous ceramic foams were developed in the heat shield: A1203, ZrO2, and SiO2.

38. Kruso, J. N., et al
SHEET BERYLLIUM – COMPOSITE STRUCTURES.
Aeronca Manufacturing Corporation, Middletown,
Ohio. Interim Technical Documentary Progress
Report. July 1962. 250p. (Contract No. (P),
AF 33(657)-7151) ASD TR 7-845 (III).

This program is directed toward the design, development of manufacturing processes, testing, and evaluation of reinforced-ceramic heat shields combined with load-bearing honeycomb-panel structure. The predominant development effort is in the application of beryllium to the load-bearing structure. A 90-inch section of a typical lifting-body re-entry vehicle will be fabricated for test under a simulated super-orbital re-entry environment. Materials selection for the structural portions include A-285 and beryllium-facing sheets. Development work is well under way on forming and brazing techniques, particularly of beryllium. Material selections for the heat shield are not final but at present a refinement of the basic 40-pounds-per-cubic-foot alumina foam with a zirconia coating is most promising for the design objective. Environmental tests of large composite panels in ram-jet exhaust and propane hot-gas facilities demonstrated good heat shield, joint, and coating performance under conditions of high pressure, noise, and temperature.

39. Krusos, J. N., W. B. Hunter, et al
SHEET BERYLLIUM – COMPOSITE STRUC-
TURES. Interim technical documentary pro-
gress rept., 1 July–30 Sep 1962. Oct 1962.
(Contract AF 33(657)7151, Proj. 7-845)
ASD TR 7-845, vol. 4. ASTIA AD-289 671.

Progress is reported on the design, development of manufacturing processes, testing, and evaluation of reinforced ceramic heat shields combined with load bearing honeycomb panel structure. The composite structure will be capable of withstanding surface temperatures in excess of 3000° F for one hour. The load bearing semi-monocoque structure will operate in temperature ranges suitable for Be, stainless steels, and superalloys. A 90-in. section of a typical lifting body re-entry vehicle will be fabricated for test under a simulated super-orbital reentry environment. Work has been performed in the definition of environment, design analysis, materials selection, and component testing. Materials selection for the structural portions include A-286 and Hastelloy C honeycomb, and A-286 and beryllium facing sheets. Material selections for the heat shield were completed and include alumina foam with a zirconia coating. Further tests were performed to define and develop the design limits of this material.

40. Lauchner, J. H., D. L. Branson and J. M. Fields, Jr.
HIGH TEMPERATURE INORGANIC STRUCTURAL
COMPOSITE MATERIALS. Mississippi State
Univ., Quart. Prog. Rept. No. 2. (Contract
AF 33(616)-7765(2)) Apr–Jun 1961.

Fiber reinforced inorganic composites were formed, phosphate corrosion studies and physical property evaluations were made. High temperature elastic constants were measured and load deformation behavior studies initiated.

41. Launcher, J. H., W. B. Hall and J. M. Fields, Jr.
HIGH TEMPERATURE INORGANIC STRUCTURAL
COMPOSITE MATERIALS. Mississippi State U.,
State College. Final rept., 14 Dec 1960–15 Dec
1961 on Nonmetallic and Composite Materials.
Nov 1962, 50p. (Contract AF 33(616)7765, Proj.
7340) ASD TDR 62-202, pt. 1. ASTIA AD-294 823.

The demand for high strength materials at elevated temperatures has resulted in the investigation of inorganic fiber reinforced-inorganic matrix composites. The first year's major effort on this project was directed toward the development of the inorganic matrix and the evaluation of the physical properties of this material. In addition, fiber protection and composite processing were studied. An aluminum phosphate matrix was developed which had the required properties of low modulus of elasticity and inelastic deformation. Differential thermal analysis and X-ray studies indicated that different phases of aluminum phosphate (analogous to silica phases) may be the cause of matrix inelastic deformation characteristics. The matrix materials developed were found to be corrosive to reinforcement fibers. Composites formed by wet layup were more corrosive than composites formed by dry pressing. Fiber protection was studied and a series of coated specimens evaluated. Several coatings indicated potential protection capabilities.

42. Leeds, D. H.
A PORTFOLIO OF EXPERIENCE IN REFRACTORY METAL PROTECTIVE SYSTEMS. Aerospace Corp., El Segundo, Calif. For Presentation at the Seventh High Temperature Composites Working Group Meeting NASA/ASD, 11–14 Mar 1963, Palo Alto, Calif.

43. Logan, I. M. and J. E. Niesse
PROCESS AND DESIGN DATA ON A BORIDE-SILICIDE COMPOSITION RESISTANT TO OXIDATION TO 2000°C. The Carborundum Company, Niagara Falls, New York. ASD, ASD-TDR-62-1055, Technical Documentary Report, Nov 1962. (Contract No. AF 33(616)-8041) 144p.

A zirconium-diboride-molybdenum-disilicide solid-solution composition was studied to establish sufficient property data so that this material can be considered for possible future applications. In the first part of this work an optimum minor addition of boron-nitride powder was determined on the basis of strength (modulus of rupture), oxidation resistance, and thermal shock behavior. Sintering aids, sintering temperature and time, temporary binders, and green-pressing techniques were studied to produce reproducible sintered material. The second part was a property-testing program at temperatures up to 2000°C (3632°F) which included oxidation resistance to convection and forced air, modulus of rupture, creep strength, modulus of elasticity, thermal expansion, thermal conductivity, thermal shock resistance, and emissivity. Where practical, standard deviations were calculated to yield reproducibility information.

44. MacNeill, C. E.
ULTRA-HIGH TEMPERATURE MATERIAL SYSTEMS FOR EXPANDABLE AEROSPACE VEHICLES. 24p. (Paper presented at the NASA-ASD Sponsored Sixth Refractory Composites Working Group Meeting, Dayton, Ohio, 17–19 Jun 1962.

A program is described that indicated that it is feasible to use a "gas plating" metamorphic-material system to form high-temperature expandable structures from

the heat generated by a re-entering space vehicle. An organometallic compound will convert on a hot surface, such as wire cloth, to produce a metallic coating. The material system described shows capabilities for use in a thermal environment of up to 2000° F and indicates that high-temperature structures may be formed by using different compounds and base materials. By utilizing engineering data developed for rigid structures, it appears feasible that expandable structures for 3000° F use could be developed. These material systems would find applications in re-entry vehicles and drag devices.

45. McCloskey, A. L., H. Steinberg, et al
RESEARCH ON INORGANIC POLYMER SYSTEMS.
United States Borax Research Corp., Anaheim, Calif. Rept. for 1 Jan–31 Dec 1961, on Non-Metallic and Composite Materials. Mar 1962. 258p. (Contract AF 33(616)7303, Proj. 7340) ASD TDR 62-251. ASTIA AD-278 147.

The preparation of new inorganic or semi-inorganic polymers which show sufficient thermal stability to meet a variety of projected Air Force operating requirements is discussed. Emphasis on inorganic systems resulted from the fact that polymers with carbon-carbon bonds in their skeletal structures or even the most favorably substituted silicon polymers fail to show the necessary stability at high temperatures. Emphasis is shifted from boron-boron and aluminum-based systems to boron-nitrogen bonded materials, and development studies of the more promising polymers were initiated. Systems with boron-oxygen bonding and with various aromatic groups in the polymer chains were also investigated. Recent emphasis was directed toward work of a more developmental nature including studies of polymer properties, polymerization techniques, and evaluation of end-use products, particularly glass fiber laminates. Some of the more promising polymers, several borazole monomers, and a borazole resin were prepared in pound quantities.

46. Micks, W. R.
COMPOSITE MATERIALS – CONSIDERATIONS FOR FUTURE RESEARCH. Santa Monica, California, The Rand Corporation. Institute of the Aerospace Sciences National Summer Meeting, Los Angeles, California, 19–22 Jun 1962. 28p. Preprint No. I.A.S. 62-167.

The present investigation is a study of important unresolved unknowns, concerning test data and information on composites, the reasons for their importance, and what could be done in the future to provide an improved basis for meaningful interpretation of research results.

47. Murphy, A. J.
MATERIALS FOR ASTRONAUTIC VEHICLES.
College of Aeronautics, Cranfield (Gt. Brit.).
Rept. no. 139. Nov 1960. ASTIA AD-260 616.
(A paper given to the AGARD Symposium on Astronautics at the University of Rome, May 1959.)

The nature of the environment in outer space and its significance for materials of construction of astronautic vehicles are considered. For the ballistic missile, ablation of surface layers on the nose cone offers the best prospect of successful heat-dissipation. The ablating material may be an organic material, e.g. synthetic resin, or a ceramic compound. For longer spells at high temperatures, as in satellites on re-entry, the alternatives are thermal insulation by non-metallic surface coatings, and skins of metals having very high melting points. Coatings which provide insulation and protection from oxidation are provided as flame-sprayed ceramic oxides, especially alumina and zirconia, or ceramics reinforced by a refractory metal grid attached to the base metal. Characteristics of materials which acquire special importance in astronautic applications are: thermal conductivity, specific heat, latent heat of fusion and evaporation, coefficient of thermal expansion, reactivity at high temperatures, sensitivity to irradiation, creep strength, resistance to high temperatures, and mechanical properties at low temperatures.

48. Neff, C. W. and R. G. Frank
REFRACTORY METALS STRUCTURAL DEVELOPMENT PROGRAM. VOLUME IV: STRUCTURAL COMPONENT DESIGN AND FABRICATION.
McDonnell Aircraft Corp., St. Louis, Mo.
Final Report. Wright-Patterson AFB, Ohio, Flight Dynamics Lab., Aug 1962. 121p.
(Contract AF 33(616)-6578) ASD-TR-61-392, vol. IV. (Available to U. S. Government agencies and contractors only)

The final component was fabricated from columbium (F-48), and a General Electric LB-2 (aluminum-chromium-silicon) slurry coating was used for oxidation protection of the component parts with the exception of fasteners. The fasteners used for final assembly were coated with Thompson-Ramo-Wooldridge (TRW) vapor deposited coating. All the fusion welded fittings were fabricated from Fansteel FS-82 columbium, the inboard rudder panels were fabricated from L-605, and the inboard fin panels were fabricated from columbium 1% Zr. The major problem areas encountered in this program were: (1) material processing, (2) joining, and (3) protection.

49. Otto, W. H., S. Dharmarajan and C. Y. Chia
POTENTIAL OF FILAMENT WOULD COMPOSITES.
Narmco Industries, Inc., San Diego, Calif. Monthly
progress rept. no. 14, 1–30 Jun 1962. 30 Jun 1962.
33p. (Contract NOw 61-0623-c) ASTIA AD-278 572.

The effect of humidity cycling on the tensile strength of single E-glass fibers coated with epoxy resin are reported for cycling periods up to five days. Experiments to study the effect of fiber tension during resin cure were initiated and stress rupture tests at room temperature are reported. Based on the large deflection theory of a homogeneous plate by Von Karman and the small deflection theory of asymmetrically laminated anisotropic plates by Stavsky and McGarry, a large deflection theory of asymmetrically laminated anisotropic plates was developed. The transverse shearing stresses and the stress normal to the plane of the plate could be computed from the governing differential equations and macroscopic equilibrium equations. To satisfy the loading conditions at the top and bottom surfaces of the plate three linear differential equations were obtained in addition to the eighth order system of nonlinear governing differential equations.

50. Otto, W. H., S. Dharmarajan, et al
POTENTIAL OF FILAMENT WOUND COM-
POSITES. Narmco Industries, Inc., San Diego,
Calif. Monthly progress rept. no. 15, 1–31 Jul
1962. 31 Jul 1962. 11p. (Contract NOw 61-0623-c)
ASTIA AD-282 545.

The effect of humidity on the tensile strength of E-glass fibers coated with epoxy resin is reported for cycling periods up to 28 days. The experimental data on the study of the effect of fiber tension during resin cure and stress rupture tests at room temperature are reported. The large deflection theory of asymmetrically laminated, anisotropic, rectangular plates under biaxial tension.

51. Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 2, 4 Jun–4 Aug 1962.
7 Sep 1962. 4p. Rept. no. ARF 2241-2.
(Contract NOw 62-0650-c) ASTIA AD-283 610.

The chemical etching of 0.0047 inch beryllium wires seems to work satisfactorily. The time required for reduction in diameter from 0.0047 inch to 0.0010 inch was of the order of 1.5 minutes. The wires reduced to 0.002 inch diameter could be handled fairly easily. However, the 0.001 inch wires were extremely fragile. The work on Be-Ag composites was continued. In view of previous difficulties, some experiments were performed on Be-Ag composites without aluminum or germanium. The work on the silver-aluminum alloys indicated that the matrix was relatively weak with tensile strengths no greater than about 60,000 psi. A number of prealloyed aluminum alloy powders were prepared by atomization from a melt. These powders were compacted and extruded at 800–900° F with a 16:1 extrusion ratio. The results of yield strength, tensile strength and elongation are summarized.

52. Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 3, 4 Aug–4 Oct 1962.
26 Oct 1962. 6p. Rept. no. ARF B241-3.
(Contract NOw 62-0650-c) ASTIA AD-287 594.

Be fiber-Ag alloy matrix composites were prepared from 0.0047 in. diam wires. Although there is an etching effect on the wire surfaces due to the high processing temperatures, the bond between Be fiber surface and Ag matrix is a coherent one. Powders were prepared by melting and atomization. The Al alloy matrix was used for preparing some extruded bars for determining the optimum heat treatment conditions. All these composites are being evaluated.

53. Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS
Armour Research Foundation, Chicago, Ill.
Bimonthly report no. 4, 4 Oct–4 Dec 1962.
4 Jan 1963. 10p. Report no. ARF-B241-4.
(Contract NOw 62-0650-c) ASTIA AD-293 259.

Work was continued on the chemical etching of drawn Be wires to reduce their diameters from 0.0047 to about 0.001 inch. Several matrix alloys were prepared by atomizing. These were prepared by first melting 2S Al in a crucible, adding the alloying elements to the melt, and disintegrating the molten stream of metal of about 100 psi pressure of dry compressed air. The powders thus collected were sieved through a 50 mesh screen and compacted in a 1-in die. In the work on Be fiber composites, the spread in the size of the fibers was so great that it was difficult to designate an average size. These fibers were mixed with plain 2S Al powder (-60 mesh), compacted in a 1-inch die at 15 tsi and extruded at temperatures below 870° F at an extrusion ratio of about 40:1. The tensile properties and elastic modulus were measured on a Hounsfield Tensometer. It was a chief objective of this series of experiments to see if these composites could be densified by extrusion techniques, and it appears that this technique is satisfactory.

54. Pearl, H. A.
COMPOSITE REFRACTORY MATERIALS FOR AEROSPACE VEHICLES RAC 798. Republic Aviation Corporation, Farmingdale, Long Island, New York.
RAD 798. 37p. (Paper presented at the NASA-ASD Sponsored Sixth Refractory Composite Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962.)

The titanium and superalloy portions of the present program have been successfully completed. Adequate know-how has been obtained to develop facilities of the efficient fabrication, machining, and joining of elemental shapes, as well as the manufacture of sandwich type panels.

Molybdenum alloys are treated with respect to formability, machinability, fastener development, joining (mechanical, fusion weld, and resistance weld), oxidation-protective-coating application and evaluation, fabrication and testing of simple structural elements (including corrugated panels), and design, fabrication, and testing of two large structural components.

55. Pezdirtz, G. F.
NONMETALLIC MATERIALS FOR SPACECRAFT. Langley Research Center, Langley Field, Va. NASA, AP-27. Dec 1962. 10p. (Paper presented at the NASA-University Conference on Science and Technology of Space Exploration, Chicago, Illinois, 1–3 Nov 1962.)

Nonmetallic materials have many unusual and desirable properties for use in spacecraft applications, but their sensitivities to the ultraviolet and high-energy ionizing radiation of space have created problems – some as yet unsolved. The problems of thermal control coatings, polymers, and composites in space applications are discussed. The need for new nonmetallic materials with unusual properties such as inorganic polymers is also examined.

56. Pezdirtz, G. F.
Composite materials in erectable space structures – echo satellites. In SOCIETY OF THE PLASTICS INDUSTRY, REINFORCED PLASTICS DIVISION, ANNUAL TECHNICAL AND MANAGEMENT CONFERENCE, 18TH PROCEEDINGS, NEW YORK, SOCIETY OF THE PLASTICS INDUSTRY, INC. 1963. 8p.

Presentation of experimental results on the successful inflation in space of the Echo satellites. Effects of space environment on materials are noted.

57. Plant, H. T., W. H. Marks, and T. J. Jordan
RESEARCH ON BINDER TECHNIQUES FOR HIGH TEMPERATURE RADOME STRUCTURES. General Electric Company, Schenectady, New York. Interim Engineering Report No. 3. 11p. (Contract No. AF 33(616)-8176)

Results of substitution of glass microspheres for particulate fibers in the silica fiber-reinforced aluminum-phosphate laminates on viscosity, and electrical properties are observed. Two formulations, however, do appear to have qualities worthy of investigation, and flexural strength given.

Asbestos was added to glass microsphere formulations.

Substitution of silica microspheres for particulate fillers results, and laminate modulus and strength using palygorskite or palygorskite paper as filler are also reported.

58. Plummer, J. H., E. M. Lindsay, et al
GLASS REINFORCEMENTS FOR FILAMENT WOUND COMPOSITES. Owens-Corning Fiberglas Corp., Toledo, Ohio. Interim engineering progress report, Aug—Oct 1962. Nov 1962. 62p. (Contract AF 33(657)9623, Proj. 8-104) ASD IR 8-104, pt. 1. ASTIA AD-296 028.

An investigation of the process for manufacturing glass filament reinforcements for filament winding plastic composite structure has been initiated. The investigation is directed toward determining what strength losses can be attributed to the manufacturing process and minimizing them. Equipment and test procedures for measuring single filament tensile strength, strand tensile strength, and for filament winding and hydroburst testing three-inch-diameter, open-end cylinders were set up and checked out. Material for the initial screening experiments to determine where strength losses occur was collected and testing started, but no significant conclusions were reached. A bibliography on the strength of glass with particular reference to fibers was compiled. A review of these articles indicates that minor glass composition changes have no effect on glass fiber strength.

59. Pollman, D.
DEVELOPMENT OF IMPROVED PROCESSES FOR FILAMENT-WOUND REINFORCED PLASTIC STRUCTURES. Aerojet-General Corp., Azusa, Calif. Interim technical progress report no. 1, 1 Oct 1962--31 Jan 1963. Feb 1963. 55p. Report no. 0714-01-1. (Contract AF 33(657)9726, Proj. 8-105) ASD IR 8-105, v1. ASTIA AD-296 859.

60. Powers, D. J.
TENSILE AND FLEXURAL TESTS ON REINFORCED PLASTICS AND ON BALSA WOOD COMPOSITES. Bell Aerosystems Co., Buffalo, N.Y. Report no. BLF 61-19(M) rev. A. 9 Oct 1961, rev. 10 Aug 1962. 19p. (Contract AF 33(657)8555) ASTIA AD-281 823.

Various composites of reinforced plastics and balsa wood were investigated for possible application in a vehicle. Tensile and flexural tests were conducted at room temperature.

61. Raynes, B. C. and R. H. Kelsey
STUDIES OF THE REINFORCEMENT OF METALS WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS). Horizons, Inc., Cleveland, Ohio. Interim report no. 1, 28 Aug 1961–21 Jan 1962. 29 Jan 1962. 12p. (Contract NOw 62-0235-c) ASTIA AD-294 636.

A study of the reinforcement of high temperature metals (in particular Nichrome alloys) with ultra high strength fibers (whiskers) has continued. The emphasis has been placed upon the development of a bond between the metal matrix and the reinforcing alumina whiskers. The extrusion-sintering composite preparation technique has been adopted as a standard approach in this work. The phenomenon of reinforcement apparently requires extremely precise control of the processes of diffusion in order to produce a chemical bond between the ceramic fiber and the metal matrix. Halides of various metals either present in the original metal alloy or deliberately added are presently under study. Reinforcement of a Nichrome V alloy consisting of an increase of almost 50% in measured tensile strength in a cold-worked composite has been achieved. Cold-worked Nichrome, prepared by the extrusion-sintering process, usually exhibits a room temperature tensile strength of about 210,000 psi; the composite specimen, reinfoced overall with only 2-1/2% by weight of alumina whiskers, showed room temperature tensile strength of just over 300,000 psi.

62. Raynes, B. C., R. H. Kelsey, and E. Wainer
STUDIES OF THE REINFORCEMENT OF METALS
WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Horizons, Inc., Cleveland, Ohio. Interim report no.
3, 1 Apr—31 May 1962. 24 Jul 1962. 14p. (Contract
NOw 62-0235-c) ASTIA AD-294 665.

Reinforced composites of Nichrome V and corundum fiber have shown tensile values from 250,000 to 300,000 psi, 25 to 50% increase over blank controls. A method for incorporating fiber in the metal matrix by melting, using CaC12 as a flux, was devised. This technique has produced reinforcement and is more easily controlled than the sintering process heretofore used. The effect of water vapor in the hydrogen atmosphere used for sintering was profound; with a dew point of 50° F, the samples cracked in rolling and were useless. Evaluation of all sintering data indicated that, although reinforcement could be achieved, the process was difficult to control, and led to data having excessive variability. This variation was alleviated to some extent by the use of the fusion method. It is significant to note, however, that when reinforcement was achieved on an unequivocal basis, the degree of reinforcement matched theoretical expectations.

63. Raynes, B. C., R. H. Kelsey, and E. Wainer
STUDIES OF THE REINFORCEMENT OF METALS
WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Horizons, Inc., Cleveland, Ohio. Interim report no.
4, 1 Jun--31 Jul 1962. 28 Sep 1962. 16p. (Contract
NOw 62-0235-c) ASTIA AD-294 637.

The reinforcement of pure hydrogen-reduced iron by alumina fibers is shown, both at room temperature and at 900° F. Stainless steel was found to wet alumina fibers in an argon atmosphere, and the possibility of direct reinforcement is indicated. Melting of prealloyed metal powders on high-purity dense sintered alumina disks showed the presence of excessive amounts of oxides, some of which attack the alumina. These were shown to be present in the metal powder. Means for removing undesirable oxides are being developed.

64. Raynes, B. C. and R. H. Kelsey
STUDIES OF THE REINFORCEMENT OF
METALS WITH ULTRA HIGH STRENGTH FIBERS
(WHISKERS). Horizons, Inc., Cleveland, Ohio.
Final report, 28 Aug 1962—27 Sep 1962.
10 Oct 1962. 44p. (Contract NOw 62-0235-c)
ASTIA AD-291 917.

High strength A1203 fibers (whiskers) have been used to reinforce 80-20 Ni-Cr alloy and Fe on a laboratory scale. The tensile strength of the Ni-Cr alloy was increased 28% by the incorporation of 3.8 wt-% Al 203 whiskers, with corresponding lower levels of reinforcement at lower fiber loadings. The tensile strength of H-reduced Fe was increased both at room temperature and at 900° F: at room temperature the average increase, with 8% fiber loading was 34%; at 900° F the average increase with the same amount of fiber was 30%. The fibers were randomly oriented in the matrix. Some insight into the role of oxides in forming this bond has been gained by melting the metal on A1203 tablets and observing the resulting interactions.

65. RESEARCH ON NEW AND IMPROVED THERMALLY-
PROTECTIVE FIBER REINFORCED COMPOSITE
MATERIALS. High Temperature Materials, Inc.,
Brighton, Massachusetts. 4p. (Contract No. AF
33(657)-8651) (Report presented at the NASA-ASD
Sponsored Refractory Composites Working Group
Meeting, Dayton, Ohio, 16—19 Jun 1962.)

The objective of the program is the improvement of composites by the modification and synthesis of new high-temperature fibers. The composites are intended for use in rocket-exhaust environments, in high-shear-force re-entry environments, and in short- and long-duration moderate-heat-flux re-entry environments. The improvement and synthesis techniques which will be employed, the fibers which will be developed, and the properties which will be measured are the subjects under discussion.

66. Rice, R. G.
COMPOSITE MATERIALS. Armed Services Technical Information Agency, Arlington, Va. Bibliography for 1952–Dec 1962. Dec 1962. Report no. ARB-14419. ASTIA AD-295 500.

Bibliography of 1,000 references covering the period from 1952–December 1962. No index or subdivisions given.

67. Rolston, J. A.
LITERATURE SURVEY ON FILAMENT-WOUND COMPOSITE STRUCTURES. Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. ASD TR 61-215. Sep 1961. 21p.

This report brings together a total of 68 abstracts of literature related to filament winding, and covers reports previous to March 1961. The abstracts are grouped into seven categories: (1) fundamental theory and fundamental relationships, (2) reinforcement materials, (3) matrix materials, (4) design, (5) mechanical properties and testing, (6) manufacturing methods, and (7) miscellaneous information.

68. Rosen, B. W.
STUDY OF THE RELATIONSHIP OF PROPERTIES OF COMPOSITE MATERIALS TO PROPERTIES OF THEIR CONSTITUENTS. General Electric Co., Space Sciences Laboratory, Philadelphia, Pa. Quarterly progress report no. 2. 28 Feb 1963. 34p. (NASA Contract NASw-470) (Available to U.S. Government agencies only.)

The principal results of the investigations of composite material behavior performed in the three-month period ending February 7, 1963, are described. Included are a failure model for fiber-reinforced composites, and experimental and theoretical elastic-constant determinations.

69. Rosen, B. and A. E. Ketler C
IMPROVED STRUCTURAL COMPOSITES (U).
Space Sciences Laboratory, General Electric Co.,
Philadelphia, Philadelphia, Pa. Report for
Oct 1961—Feb 1962 on Advanced Re-entry
Vehicles Program (U). 13 Apr 1962. 38p.
Document no. 62SD474. (Contract AF 04(647)617)
ASTIA AD-330 138. CONFIDENTIAL REPORT

70. Schmidt, D. L. and W. C. Jones
CARBON-BASE FIBER REINFORCED PLASTICS.
Directorate of Materials and Processes, Aeronautical Systems Division, Wright-Patterson Air
Force Base, Ohio. Final report, Oct 1961—May 1962
on Nonmetallic and Composite Materials. Aug 1962.
60p. (Proj. 7340) ASD TDR 62-635. ASTIA AD-288 289.

Current research on high-temperature materials has led to the development of a new class of nonmelting filamentous materials. These fibers are carbonaceous in composition and hold great promise for use as reinforcing agents in both structural and ablative plastic composites. First generation developments in carbon-base fiber technology are reported. Techniques for synthesizing the fibered materials are discussed, together with the properties and characteristics of available materials. Unique plastic composites were prepared using carbonbase fibers and fabrics. Initial empirical results indicate that the composites are useful for both high-temperature structural and ablative purposes.

71. Shaffer, P. T. and D. P. Hasselman
STUDY OF COMBINATIONS OF HIGH AND LOW
ELASTIC MODULUS CERAMIC MATERIALS.
The Carborundum Co., Niagara Falls, N.Y.
Sixth quarterly report, 15 Jun—15 Sep 1961.
18 Sep 1961. 12p. (Contract AF 33(616)6806)

In the period covered by this report additional property values were obtained for the composite bodies of zirconium carbide-graphite and silicon carbide graphite. Thermal shock tests on spheres composed of zirconium carbide-graphite were carried out using a radiation-convection boundary condition. The actual volume fraction of graphite in the zirconium carbide-graphite composites is being determined by metallographic means.

Calculations were made of the maximum thermal stress, time of maximum stress, and the center, surface and mean temperature at the time of maximum stress in a spherical body subjected to transient thermal shock. On the basis of these calculations the predicted thermal shock behavior of spherical shapes as investigated by Crandall and Ging were recalculated. To simply these calculations a graphical method was devised. Good agreement with experimental values was obtained.

72. Sharkitt, R. L.
HIGH TEMPERATURE RESISTANT BERYLLIA FIBER-REINFORCED STRUCTURAL COMPOSITES. National Beryllia Corp., Haskell, N.J. Fifth Quarterly Report, 15 Mar–Jun 1962. 34p. (Contract AF 33(616)8066) (Available as NASA X63-10237.)

Studies of the basic physical and crystallographic properties of BeO fibers and their effect on the mechanical properties of various matrix materials.

73. Sharkitt, R. L.
HIGH-TEMPERATURE RESISTANT BERYLLIA FIBER-REINFORCED STRUCTURAL COMPOSITES. National Beryllia Corp., Haskell, N.J. Sixth Quarterly Report for the period 15 Jun–15 Nov 1962. 1962. 28p. (Contract AF 33(616)-8066) (Available as NASA X63-11688) (Available to U.S. Government agencies and contractors only.)

High-temperature resistant beryllium oxide fiber-reinforced structural composites are reviewed. Calibration of the zone refining and leveling equipment has been completed, and control parameters have been established using aluminum oxide rods. Results of initial runs made with beryllium oxide polycrystalline extruded rods indicate that zone thermal treatment of 1625 C for one hour, at a speed of 1.8 inches per hour, altered the physical properties such that the grain boundaries were less susceptible to chemical attack. The material appeared less friable than sections of the same rod treated at 300 C to 1400 C for one hour, or than untreated sections. The effects of seeding-nucleation of body centered cubic materials such as tungsten, molybdenum, and

tantalum have been encouraging as possible methods for promoting growth of beryllium oxide monocrystalline fibers. Work with resins has established the fact that an acceptable high modulus resin matrix material may be produced using Epon 815 and a diaminodiphenyl sulfone catalyst. The addition of beryllium oxide monocrystalline fibers to this higher modulus resin is considerably easier than with several other resins tested because of the lower viscosity and longer pot life. Groups of fibers may be pre-positioned and the resin cast around them without excessive disruption of alignment or packing. This technique has yielded fiber-resin composites with more than 25% fibers.

74. Shibley, A. M., H. L. Peritt, and M. Eig
A SURVEY OF FILAMENT WINDING: MATERIALS, DESIGN CRITERIA, MILITARY APPLICATIONS. Plastics Technical Evaluation Center (PLASTEC) Picatinny Arsenal, Dover, New Jersey. PLASTEC Report 10. May 1962. 251p.

Filament winding is about to evolve as an industry, separate and unique from the rest of the reinforced plastics field. This is in line with the times in which structures combining great strength with lightness of weight are increasingly in demand. This report surveys the filamentary field, but primarily from the military standpoint. It covers design analysis, raw materials, test methods, and processing techniques. Included is a summary of related contracts and a bibliography of 169 items. Rocket motor cases continue to be a major application. Hydrospace vehicles, subjected to high external pressure, offer a future potential. Developments in this direction are underway. In handling design and stress problems, the "netting analysis" remains the major tool. It has received a number of refinements regarding end closures. With raw materials, greatest emphasis has been placed on fiberglass reinforcements. Today, more resin systems are available and are being exploited. The use of pre-impregnated filaments is more widespread. Test methods, particularly nondestructive testing, present problems. There is also need for improved quality control and a sound basis for standardization. The winding process itself has come in for improvements dealing with patterns, tension control, resin control, curing, and reproducibility. Included is the investigation of suitable mandrel materials and designs. The survey of present contracts reveals that all major areas are being investigated by Government agencies.

75. Smith, L. L.
COMPOSITE INORGANIC RESILIENT SEAL MATERIALS. Armour Research Foundation, Chicago, Ill. Progress rept. no. 8, 1 Jul–30 Sep 1962. 30 Sep 1962. 16p. (Contract AF 33(616)7310, Proj. 1(8-7340)) ASTIA AD-291 985.

Research was conducted on composite materials for use as fluid seals in the cryogenic to 2000°F range. The composite materials consist of fibers, usually metallic, in a metallic or polymeric matrix, such as stainless steel fibers with a Ag filler. A new fixture for evaluating reciprocating shaft seals was built, research on low and high pressure seals was performed, and mechanical evaluation at room and elevated temperatures was started.

76. Materials Advisory Board, National Research Council, Washington, D. C.
STATE OF THE ART ON POWDER METALLURGY, BY THE PANEL ON CASTING AND POWDER METALLURGY OF THE COMMITTEE ON THE DEVELOPMENT OF MANUFACTURING PROCESSES FOR AEROSPACE MATERIALS. Progress rept. no. 4. 28 May 1962. 41p. Rept. no. MAB-139-M(C4). (Contract SD-118) ASTIA AD-278 274.

A review was made of processes for the consolidation of powders, and their subsequent sintering and post-treatments. The art appears to be moderately advanced and offers no major obstacle to its incorporation into aerospace processing requirements. There are areas which offer opportunities for improvement. These are powders of beryllium and refractory metals and alloys, powder rolling to produce thin wide sheet of varying densities or permeabilities, sintering modifications to enable lower temperature or shorter times for refractory metals, and the introduction of composites having desired properties of high strength low weight through the use of whiskers or high-strength fibers. Since beryllium, tungsten, and molybdenum are produced in the powder form, it is probable that powder metallurgy will continue to play a major role in their future. The requirements for composites and porous structures also preclude most other processes and serve to emphasize the need for attention to be given to powder metallurgy.

77. Sterry, J. P., W. L. Lachman and J. Stites
CERAMIC FIBERS FOR REFRACTORY COMPOSITES. Gardena, California, H. I. Thompson Fiber Glass Company. (Paper presented at the NASA-ASD Sponsored Sixth Refractory Composite Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962.) 4p.

This brief paper is a progress report discussion of ceramic fiber research oriented toward ceramic fibers for high-temperature composites. Refractory composites will consist of metal or ceramic matrices combined with ceramic fiber.

78. Stevens, D.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED LAMINATES AS ENGINEERING STRUCTURAL MATERIALS. Narmco Corporation, San Diego, California. Final Report. Mar 1962. 52p. (Contract No. NOw 61-0305-c)

Flake composites were investigated and their structural potential and properties are discussed. Topics included are: fabrication by the inflatable mandrel method, filament winding under tension, centrifugal casting, and the hydroclave method; notch sensitivity of flake-reinforced composites; electrical properties of flake composites; cryogenic tests; incorporation of carbon black filler; and thread strength. Advantageous applications of flake composites are reported. Combinations of flake with glass fibers were tested and their structural potential is discussed. The theoretical work conducted during the period covered by this report predicts inherent stress concentrations of up to eight times the nominal stress in circular flake composites. The fabrication of cylinders and shapes other than flat plates using preformed b-staged sheets of flake composite material and fluid molding pressure is reported to have advantages over other fabrication methods.

79. Stevens, D. and W. Otto
POTENTIAL OF FILAMENT WOUND COMPOSITES. Narmco Industries, Inc., San Diego, Calif. Monthly progress rept. no. 16, 1–31 Aug 1962. Aug 1962. 11p. (Contract NOw 61-0623-c) ASTIA AD-284 632.

Measurements of the effect of tension on monofilament during resin cure are reported for fiber stress from 36,000 psi to 160,000 psi. Tests on the effects of humidity cycling of epoxy coated single E-Glass fibers were completed and the results are reported. The static fatigue studies on virgin E-glass fibers coated with epoxy resin were completed. The results are reported for temperatures up to 600° F and load durations up to 10 min. A method of experimentally confirming the derived biaxial stress-strain equations is described along with an apparatus for making bending and twisting load-deflection tests. A device constructed to make biaxial stress-strain and photoelastic tests is described.

80. Stevens, D. and W. Otto
POTENTIAL OF FILAMENT WOUND COMPOSITES. Narmco Industries, Inc., San Diego, Calif. Monthly progress rept. no. 17, 1–30 Sep 1962. 30 Sep 1962. 15p. (Contract NOw 61-0623-c) ASTIA AD-286 894.

The effect of tension during cure on the strength of glass roving and the effect of humidity cycling on the strength of single uncoated E-glass fibers is reported. A description is presented of the apparatus used for photoelastic evaluation of biaxial stress in specially prepared Maltese cross test specimens. A failure sequence for one of these specimens is shown.

81. Stevens, D. and W. Otto
POTENTIAL OF FILAMENT WOUND COMPOSITES. Narmco Industries, Inc., San Diego, Calif. Monthly progress rept. no. 18, 1–31 Oct 1962. 31 Oct 1962. 19p. (Contract NOw 61-0623-c) ASTIA AD-289 388.

A number of collimation tests were made on various production strands and roving, and the test data are tabulated. Continued work on single-filament pull-out tests is reported and the developed test procedures are described. Biaxial tests on Scotchply fiber glass composites are described. The test specimens in the maltese cross configuration are described along with the test procedure. Some surprising strength and stress-strain data are reported, and future tests to explain the data are outlined.

82. Stevens, D. and W. H. Otto
POTENTIAL OF FILAMENT WOUND COMPOSITES. Narmco Industries, Inc., San Diego, Calif. Monthly progress rept. no. 19, 1–30 Nov 1962. Nov 1962. 12p. (Contract NOw 61-0623-c) ASTIA AD-291 539.

The structural advantages of coating the fibers in a fiberglass composite with a ductile resin were investigated. It was hypothesized that such a coating might minimize the effects of crazing of the relatively brittle resin matrix by stopping craze cracks before they reach the glass fibers. In addition, the ductile coating might reduce any stress concentrations around broken fibers where load must be transferred into the broken fiber by resin shear. In an effort to detect the latter effect, fiber pull-out specimens were prepared using nylon coated fibers. Data on these tests are tabulated. Photoelastic specimens were prepared using Nylon coated fibers and containing discontinuities in the fibers. Biaxial tests were conducted on Scotchply maltese crosses simulating a filament-wound fiber-glass laminate. The data presented indicates that the maltese cross in the configuration used has its limitations, but among its advantages is the fact that it provides a cheap and convenient method of testing materials under biaxial loads.

83. Stevens, D. and W. H. Otto
POTENTIAL OF FILAMENT WOUND COMPOSITES.
Narmco Industries, Inc., San Diego, Calif.
Monthly progress rept. no. 20, 1–31 Dec 1962.
Dec 1962. 12p. (Contract NOw 61-0623-c) ASTIA
AD-295 643.

Single filament pull-out tests of fiber spacings of approximately 0.010 in. and 0.050 in. are reported. The completed humidity cycling tests are reported for fibers with and without resin coating. Biaxial tests on fiberglass laminates are described and the stress-strain data tabulated.

84. Strauss, E. L.
The application of resin-impregnated porous
ceramics to reentry vehicle heat shields. In
PROC. CONF. AERODYN. HEATED STRUCT.,
CAMBRIDGE, MASS. 1961. Martin Co.,
Baltimore, Md. 1962. p. 7–27.

A new materials concept, resin-impregnated porous ceramics, was developed particularly for thermal protection of glide and lifting body reentry vehicles. Resin impregnation increases the strength and thermal shock resistance, reduces the net heat transfer through the material, and permits exposure to higher heat fluxes without exceeding the melting or decompn. temp. of the ceramic. The ceramic will also maintain its original aerodynamic contour up to this temperature. Surface temps. to 4000° F were studied. Ceramic foams of SiC, Al_2O_3, and ZrO_2 with an open cell porosity of 80–90% and phenolic resins were investigated. When subjected to reentry heating conditions, cooling comes primarily from radiation supplemented by mass transfer-cooling from gaseous products of resin pyrolysis. The combination of a thin impregnated ceramic plus structural cooling results in a min.-wt. heat shield, with ZrO_2 being the best material studied. Such a system, designed to withstand a 10-min. heating pulse and a max. heat flux of 160 B.t.u./sq. ft. and total heat input of 24,000 B.t.u./sq. ft., weighs approx. 8.95 lb./sq. ft. Temperature on the backside will be $< 500°$ F at the end of the heat cycle.

85. Sutton, W. H., J. Chorné, and A. Gatti
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS. General Electric, Cincinnati, Ohio. Bureau of Naval Weapons, Eleventh Progress Report, Feb 1963. 36p. (Contract No. NOw-60-0465-d)

The purpose of this program is to develop new composite materials for high-strength, structural applications at elevated temperatures. The approach has been that of reinforcing metals with ultra-high-strength single-crystal filaments (whiskers), with emphasis being placed on silver - α - Al_2O_3 (whiskers) composites. The progress for this period is summarized: (1) The studies on the growth of α - Al_2O_3 whiskers have resulted in substrate materials which will favor growth by a continuous process, and the preliminary design of a continuous process furnace was completed; (2) A marked improvement in the microstructure of the composites has resulted from improved fabrication procedures; (3) A system for fabricating composites by vacuum-pressure infiltration under controlled conditions is being constructed; (4) Several composites were tested at room temperature, and the greatest strength achieved was 232,000 psi in tension for a silver composite containing 24 v/o whiskers; (5) Over thirty metals were considered for future studies on more refractory composites.

86. Sutton, W. H. and P. D. Gorsuch
INVESTIGATION OF WHISKER REINFORCED METALLIC COMPOSITES. General Electric Company, Philadelphia, Pennsylvania. SSL 62-5, report presented at the NASA-ASD Sponsored Sixth Refractory Composites Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962. 5 p.

The purpose of this investigation is to establish the feasibility of whisker reinforcement in metals, and to develop, ultimately, high-strength composites for elevated temperature applications. In order to conduct experimental studies, sapphire (α - Al_2O_3)

whiskers were grown by a vapor-deposition process, where aluminum is volatilized in a hydrogen atmosphere at temperatures above 1400°C. Moisture is introduced to the system so that it can react with the aluminum vapor to form Al_2O_3 and, under favorable conditions, single crystals can be grown. The strength of composites containing various percentages of nickel-coated whiskers is shown. Results are noteworthy since they show (1) that it is possible for a metallic phase to transfer effectively the load to the whisker reinforcement, and (2) that the strength of the whiskers is not significantly impaired during the period of contact with the molten metal.

87. Talley, C. P., W. J. Clark, et al
BORON REINFORCEMENTS FOR STRUCTURAL COMPOSITES. Texaco Experiment, Inc., Richmond, Va. Summary rept. no. 1, 15 Mar–15 Dec 1961. 15 Mar 1962. 122p. Rept. no. TP-188. (Contract AF 33(616)8067, Proj. 7340) ASD TDR 62-257. ASTIA AD-296 575.

B and B compounds are of interest as reinforcements for structural composites because of outstanding mechanical properties. B filaments, prepared by chemical vapor plating have strengths of approx. 500,000 psi and moduli of approx. 55,000,000 psi. Some filaments gave strengths as high as 1.0 x 10 to the 6th power psi. A laboratory scale continuous process was developed for producing B filaments of high strength and modulus. Continuous lengths of uniform B filaments, about 2–4 mils in dia. and over 700 ft long, were produced and wound onto spools. Thus far, filaments from this continuous process have strengths of approx. 250,000 psi and moduli of 55,000,000 psi. A number of filaments had strengths over 400,000 psi. At temperatures as high as 1800°F the filaments retained about 60% of their room temperature strength. Slow etching in boiling nitric acid increased strengths up to 1.4 x 10 to the 5th power psi over original room temperature strength. Tests on small composite structures containing up to 64 B filaments bonded with epoxy resin indicated high conversion of filament to composite strength and modulus resulting in composite specific strength and modulus as high as 3.4 x 10 to the 6th power and 448 x 10 to the 6th power, respectively.

88. Walton, J. D. and N. E. Poulos
METAL FIBER REINFORCED CERAMICS. Summary of work done from 1 Jul 1961 – 31 May 1962, presented at the NASA-ASD Sponsored Sixth Refractory Composites Working Group Meeting, Dayton, Ohio, 16–19 Jun 1962. 16p.

The refractory composite work done at Georgia Tech during the past year envolved preliminary investigation on metal fiber reinforcement of ceramics. These investigations included literature search and some compositional studies. The preliminary laboratory efforts included attempts to reinforce ceramics by incorporating 0.002-inch diameter by 1/8-inch long Karma (80 Ni - 20 Cr) wire fibers and 430 stainless steel wool fibers in fused silica and Al_2O_3 slips.

89. Wehr, A. G., W. B. Hall and J. H. Lauchner
HIGH TEMPERATURE INORGANIC STRUCTURAL COMPOSITE MATERIALS. Aeronautical Systems Division, Dir/Materials & Processes, Nonmetallic Materials Lab, Wright-Patterson AFB, Ohio. Rpt. No. ASD-TDR-62-202, Pt. II. Final report, Jan 1963. 60p.

Two phosphate bonded matrix materials for a composite system were studied. Polymorphism of the aluminum phosphate was responsible for wide variance in physical properties of the matrix materials. Corrosion varied as method of processing with wet layup specimens being more corrosive and dry pressed specimens being least corrosive. Boron fibers were investigated as a possible reinforcement material. Boron fibers were more corrosive resistant than glass fibers, but also were more brittle presenting a processing problem. Microscopic examination of the fibers revealed several interesting structural habits of these fibers. Strength properties of the composites were determined on an automatic stress-strain apparatus designed and built specifically for that purpose.

90. Yurenka, S., H. S. Daley and T. Siuta
HIGH TEMPERATURE RESINS, ANALYSIS OF PROCESS PARAMETERS, AND EVALUATION PROCEDURES FOR FILAMENT WOUND COMPOSITES. PART III. EVALUATION PROCEDURES. N armco Industries Inc., San Diego, Calif. Final rept., 13 Jul 1959 – 31 Dec 1960, on Nonmetallic and Composite Materials. Jun 1962. 217p. (Contract AF 33(616)-6737, Proj. 7340) WADD TR 60-791, pt. 3. ASTIA AD-282 790.

This report presents the results of Phase III on 'Evaluation Procedures for Filament Wound Composites.' The objective was to determine the most significant basic mechanical properties of filamont wound composites, and to provide optimum standardized test methods and procedures for defining them at room and elevated temperatures. The program included the design and fabrication of a versatile laboratory filament winding machine to fabricate these specimens. An account of the various test specimen configurations considered is presented, along with a detailed discussion of those actually evaluated. Detailed fabrication instructions for producing the basic specimen and some of its variations were determined. Winding machine operating and maintenance instructions are presented in as much detail as possible.

SUBJECT INDEX

(Numbers Refer to Citations)

SUBJECT INDEX (Continued)
(Numbers Refer to Citations)

AUTHOR INDEX

(Numbers Refer to Citations)

AUTHOR INDEX (Continued)

(Numbers Refer to Citations)

AUTHOR INDEX (Continued)
(Numbers Refer to Citations)

AUTHOR INDEX (Continued)
(Numbers Refer to Citations)

CORPORATE SOURCE INDEX
(Numbers Refer to Citations)

CORPORATE SOURCE INDEX (Continued)

(Numbers Refer to Citations)